Core aspects of the revised Speech Learning Model (SLM-r)

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This lecture series

Presents an overview of research on
the characteristics, consequences, and causes
of foreign accented speech in perception and in production,
and the methods used to study them.

Stucture:

1. Social, psychological, and communicative consequences of foreign accentedness
2. Predicting difficulty in L2 speech learning
3. **Core aspects of the revised Speech Learning Model (SLM-r)**
4. Do cross-language phonetic relationships provide a full account of L2 speech learning problems?

Core aspects of the revised Speech Learning Model (SLM-r)

Structure of talk:

- What is the Speech Learning Model?
- Unchanged aspects of the SLM in the SLM-r
- Clarifications of the SLM in the SLM-r
- New aspects of the SLM-r
- Open questions

What is the Speech Learning Model?

One way to answer that question:

A reaction to the failures of the

- Contrastive Analysis (CA)
- Critical Period Hypothesis (CPH)

to account for L2 speech learning

What's wrong with the CA and the CPH?

What's wrong with Contrastive Analysis?

CA: Comparison of phoneme inventories of two languages

→Learning problems

CA predicts:

L2 phonemes without a counterpart in L1: Difficult to learn

L2 phonemes with a counterpart in L1: Easy to learn

Main problem: Evidently wrong predictions

Failure importantly due to disrespect for phonetic substance:

The "same" phoneme may differ greatly in implementation, e.g. /t/:
initially [t], [t^h], [t^{sh}]; finally [t], [$t̚$], [ʔ]

What's wrong with the Critical Period Hypothesis?

CPH: Addresses the language learning paradox:

	Adults	Children
General mental abilities	+	-
Language learning abilities	-	+

Lenneberg (1967), The Biological Basis of Language

During the critical period, the individual "appears to be most sensitive to stimuli … and to preserve some innate flexibility for the organization of brain functions to carry out the complex integration of subprocesses necessary for the smooth elaboration of speech and language. After puberty, the ability for self-organization and adjustment to the physiological demands of verbal behavior quickly declines. The brain behaves as if it has become set in its ways …" (Lenneberg 1967, 158)

What's wrong with the Critical Period Hypothesis?

CPH claims that language learning ability is drastically reduced after puberty.

NOT SO

1. No study has convincingly shown a discontinuity in langage learning ability around puberty
2. Speech perception and production abilities can be successfully shaped through training "regimes" (evidence from the lab)
3. Speech perception and production abilities change as a function of L2 experience (evidence from naturalistic learning)
4. Apparent decline in speech perception abilities reflects a shift in attention, not neural atrophy (evidence from the lab)

Response to failures of CA and CPH:

Flege's (1995) Speech Learning Model (SLM)

SLM proposes: L2 learners of all ages exploit the same mechanisms and processes used earlier for L1 speech learning, including the ability to create new phonetic categories for certain L2 sounds.

Realization of this ability depends on

- State of the development of previously learned languages
- Quality and quantity of L2 experience
- Relation of L2 sounds to native categories

Core aspects of the revised Speech Learning Model (SLM-r)

Structure of talk:

- What is the Speech Learning Model?
- **Unchanged aspects of the SLM in the SLM-r**
- Clarifications of the SLM in the SLM-r
- New aspects of the SLM-r
- Open questions

Unchanged aspects of the SLM in the SLM-r

Most important aspects of SLM retained in SLM-r:

- Age: No biologically-based limit to speech learning ability

  → Life-long learning: Phonetic category formation possible regardless of age

- Learnability is a function of perceived cross-language similarity

Unchanged aspects of the SLM in the SLM-r

Most important aspects of SLM retained in SLM-r:

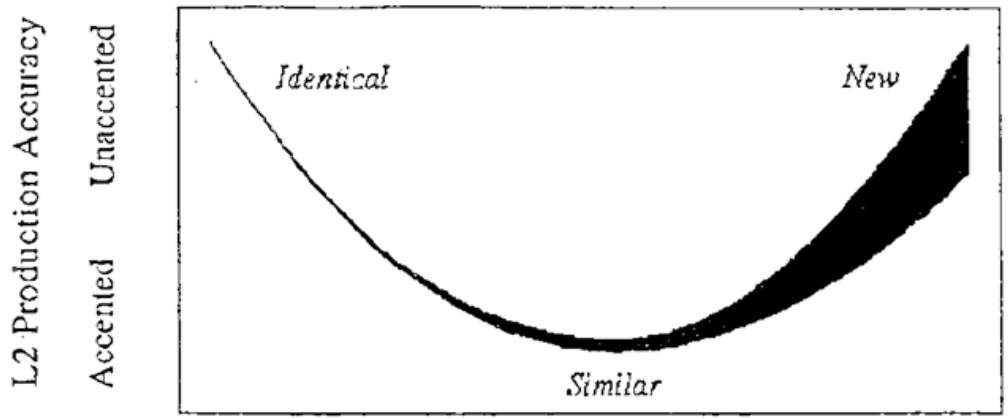
"Like its predecessor, the SLM-r assumes that L2 learners of any age make use of the same mechanisms and processes to learn L2 speech that children exploit when learning their L1.

Native vs. nonnative differences in L2 production and perception are ubiquitous not because humans lose the capacity to learn speech at a certain stage of neuro-cognitive development but because applying the mechanisms and processes that functioned "perfectly" in L1 acquisition to the sounds of an L2 does not yield the same results." (Flege & Bohn 2021, 23)

Unchanged aspects of the SLM in the SLM-r

SLM hypotheses

Hypothesis: The greater the perceived dissimilarity of an L2 sound from the closet L1 sound, the more likely a new category will be formed for the L2 sound



Example of successful SLM prediction of L2 speech learning

The case of L2 Danish /y/ – /u/

[y] – [u]

L1 Spanish /u/

[u]

L1 English /u/

[ʉ]

Example of successful SLM prediction of L2 speech learning

Garibaldi & Bohn (2017)

Production of Danish /y/, /u/, /i/
by 10 L1 speakers of

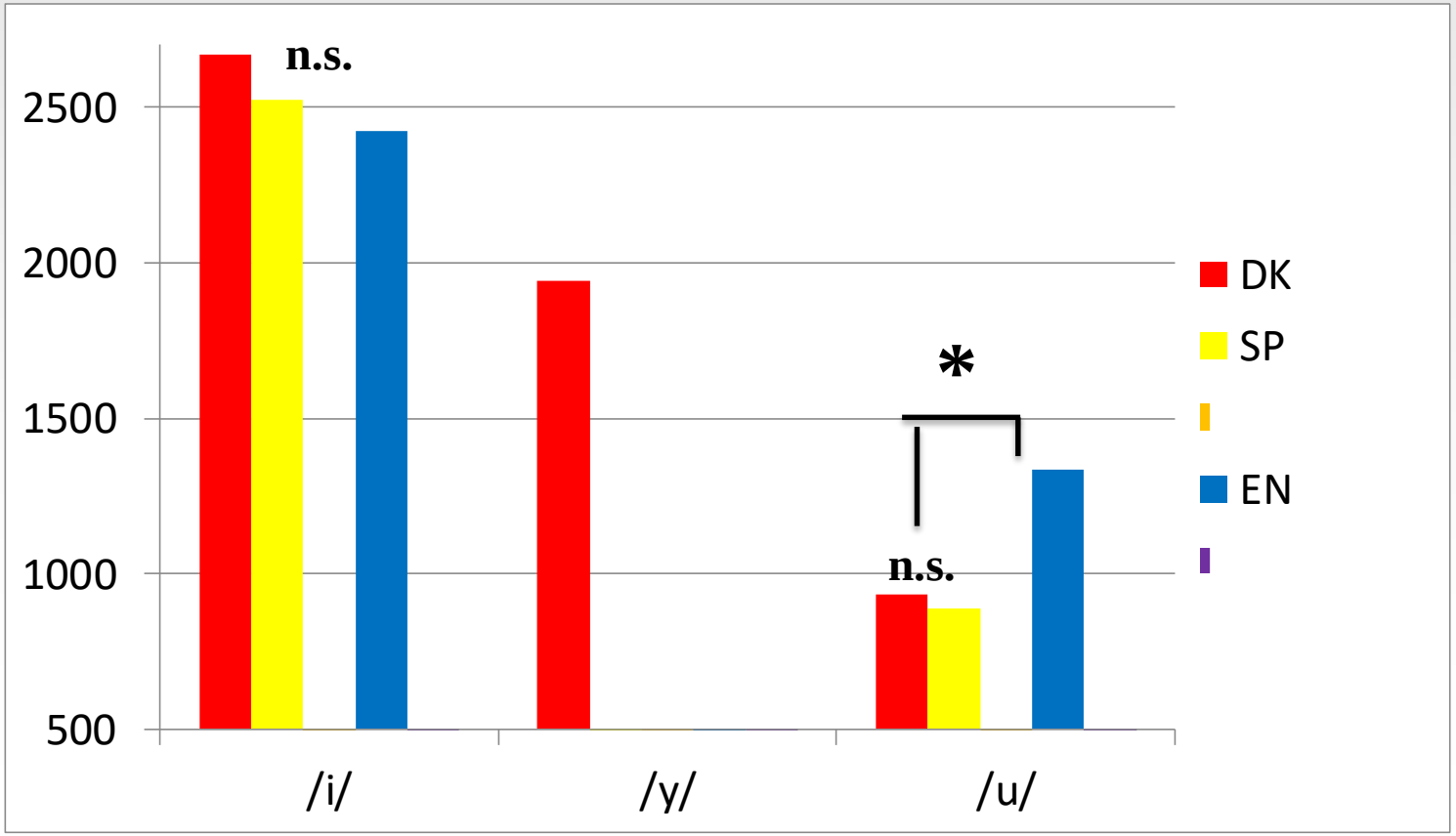
Spanish (LOR in Denmark: m = 10.5 years)

English (LOR in Denmark: m = 12.0 years)

daily use of Danish

Example of successful SLM prediction of L2 speech learning

F2 for /i, y, u/ in L1 Danish, L1 Spanish, L1 English



Example of successful SLM prediction of L2 speech learning

Perceptual assimilation / Interlingual identification

Procedure:

Identification of DK [di, dy, du]

as EN <doo> or <dee> (EN listeners),

as SP <tu> or <ti> (SP listeners).

Goodness of fit: 1 (bad) to 5 (perfect)

Example of successful SLM p0rediction of L2 speech learning

Perceptual assimilation / Interlingual identification

Danish stimuli	Spanish response		English response	
	/i/	/u/	/i/	/u/
[i]	100 (3.7)		100 (3.3)	
[y]	33.3 (2.1)	66.7 (2.0)		100 (2.4)
[u]		100 (3.6)		100 (3.2)

Mean percent identification of DK [i y, u] as L1 /i/ or /u/ by SP and EN listeners. Goodness ratings (1 = bad, 5 = perfect) in parenthesis

Example of successful SLM prediction of L2 speech learning

Perceptual assimilation / Interlingual identification

DK [y] → **SP** /i/, **SP** /u/ DK [u] → **SP** /u/

In terms of SLM: DK [y] evades equivalence classification

DK [y] → **EN** /u/ DK [u] → **EN** /u/

In terms of SLM: DK [y] equivalence-classified with EN /u/

Example of successful SLM prediction of L2 speech learning

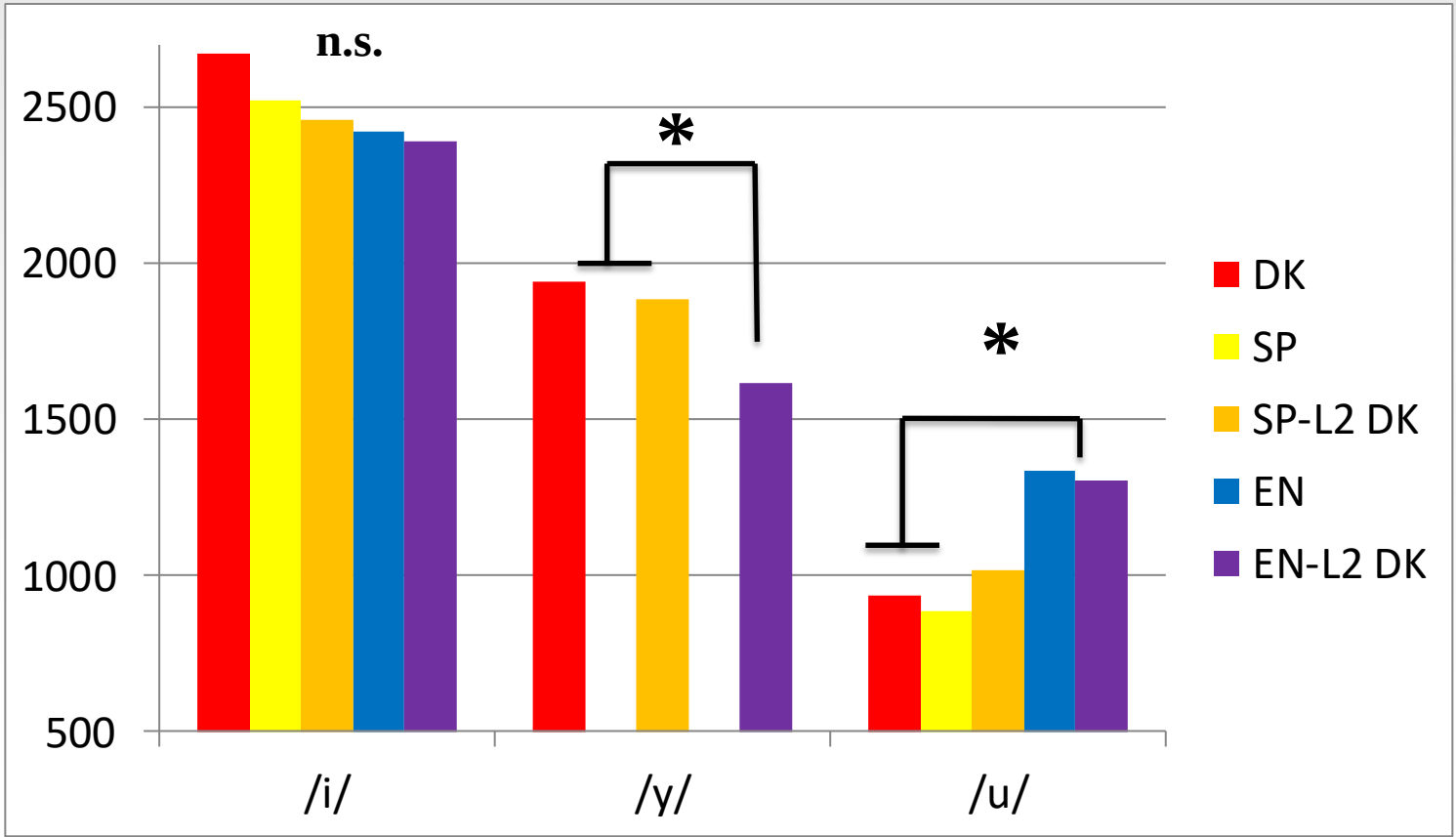
Summary of predictions based on cross-language phonetic similarity:

Experienced L1 SP speakers will produce DK /y/ correctly (no equivalence classification)

Experienced L1 EN speakers will not produce DK /y/ and /u/ correctly (equivalence classification with EN /u/, realized as [ʉ])

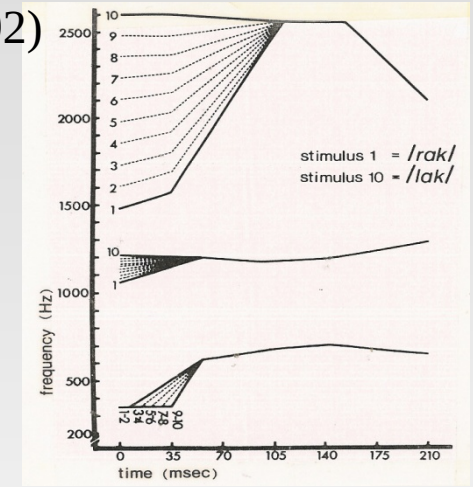
Example of successful SLM prediction of L2 speech learning

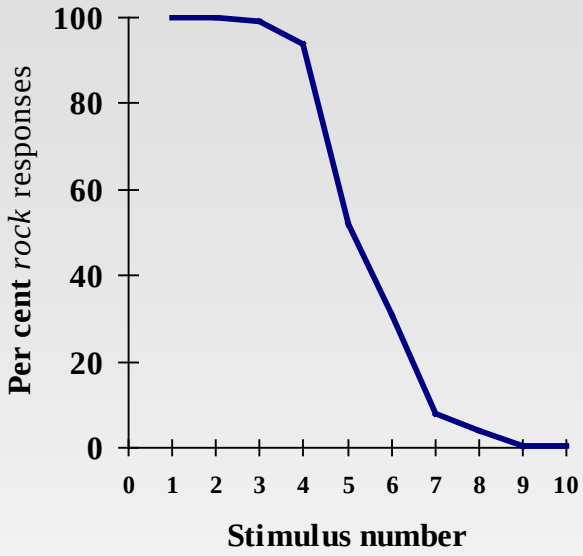
F2 for /i, y, u/ in L1 Danish, L1 Spanish, L1 English and L2 DK



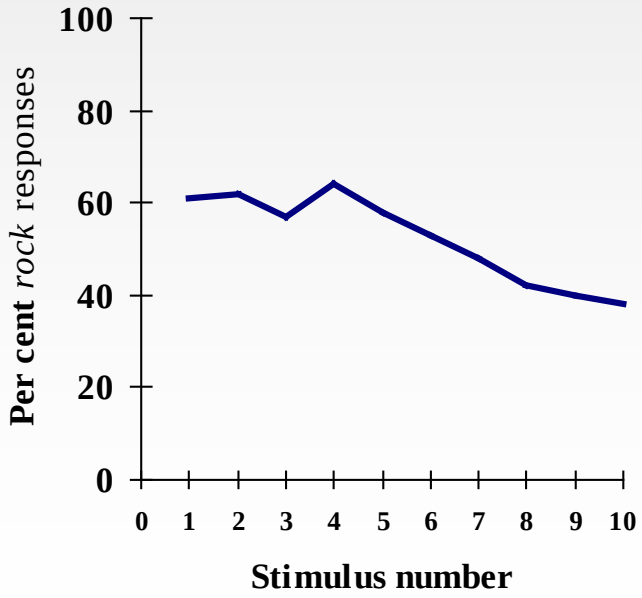
Example of successful SLM prediction of L2 speech learning

Halle, Best & Levitt (1999)
and Best & Strange (1992)

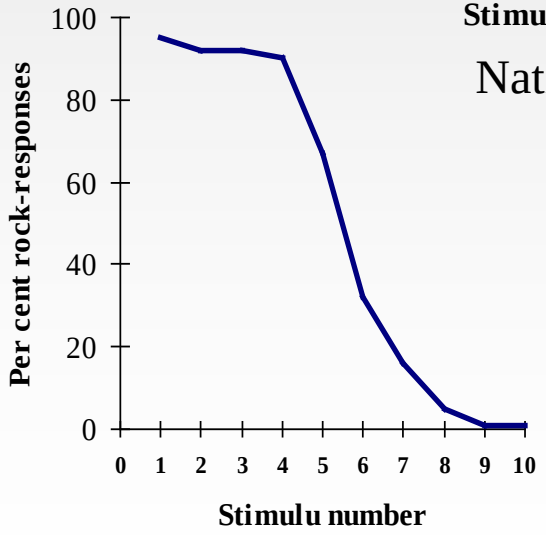




Native English



Native Japanese - inexperienced



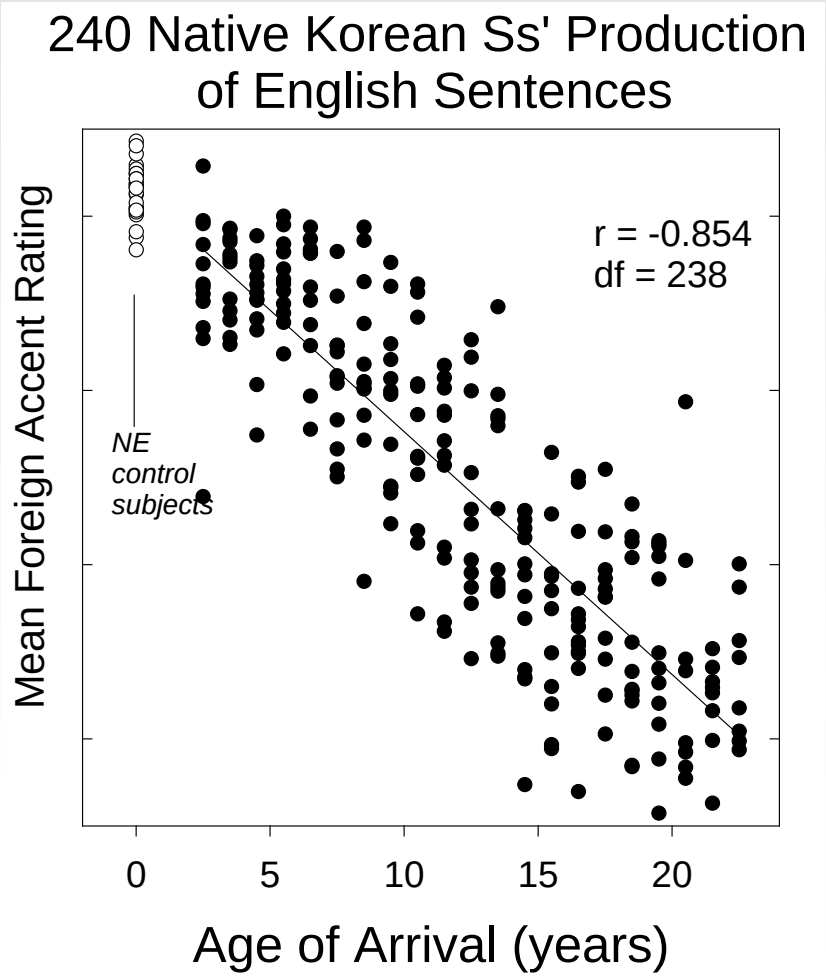
Native Japanese - experienced

Unchanged aspects of the SLM in the SLM-r

So how do SLM and SLM-r account for age effects?

Clearly, age effects do exist:

Flege, Yeni-Komshian & Liu (1999)

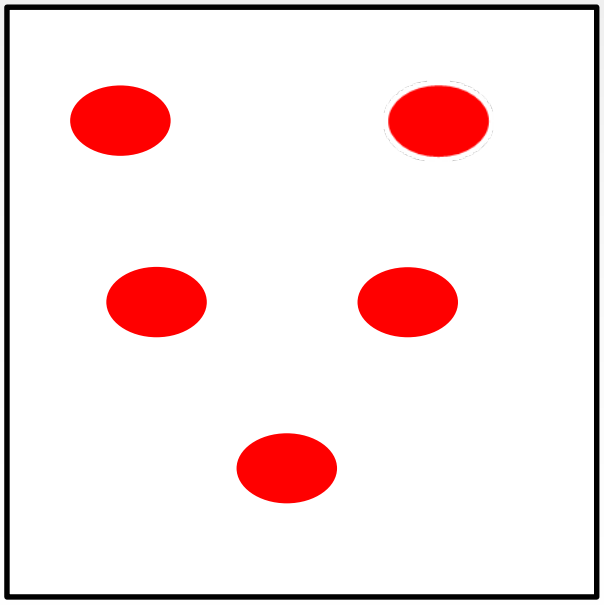


SLM and SLM-r:
Children are more likely than adults to form new categories for L2 sounds

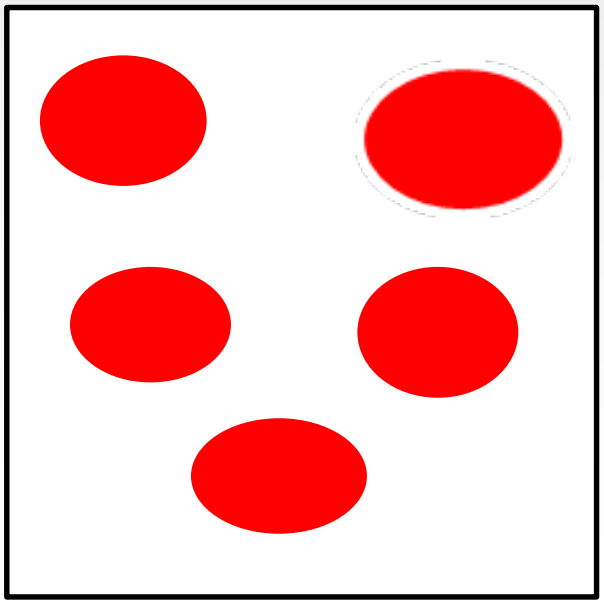
How do SLM and SLM-r account for age effects?

Schematic example of evolution of phonetic categories over childhood – adolescence – adulthood
to reflect the properties of the phones identified as a realization of a category

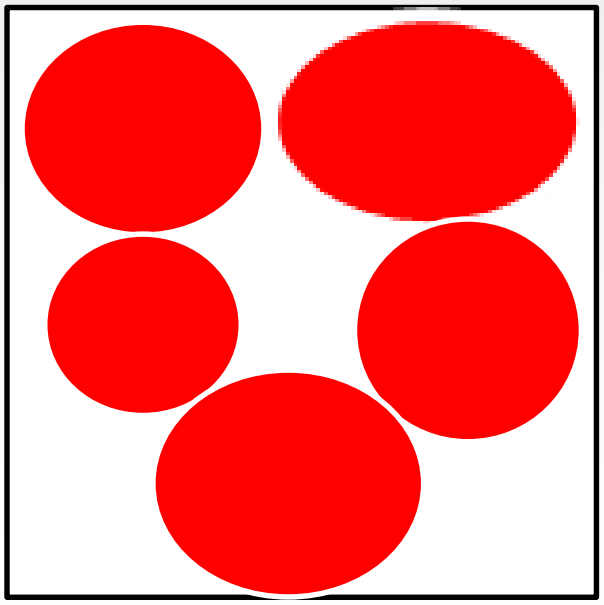
Childhood



Adolescence



Adulthood

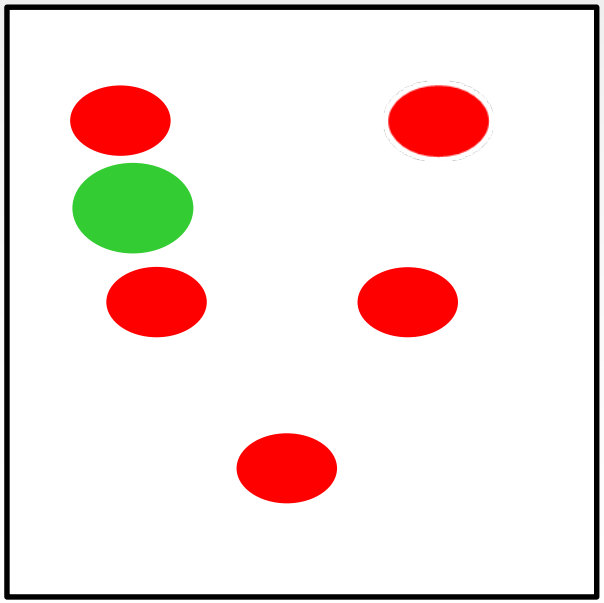


How do SLM and SLM-r account for age effects?

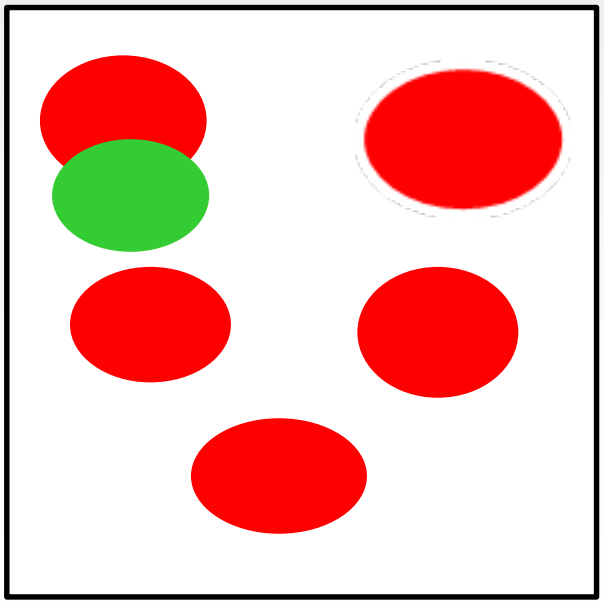
-> One important reason for age effects:
Expansion of L1 phonetic categories leaves less and less space for establishment of new L2 categories

New category formation <----------> equivalence classification

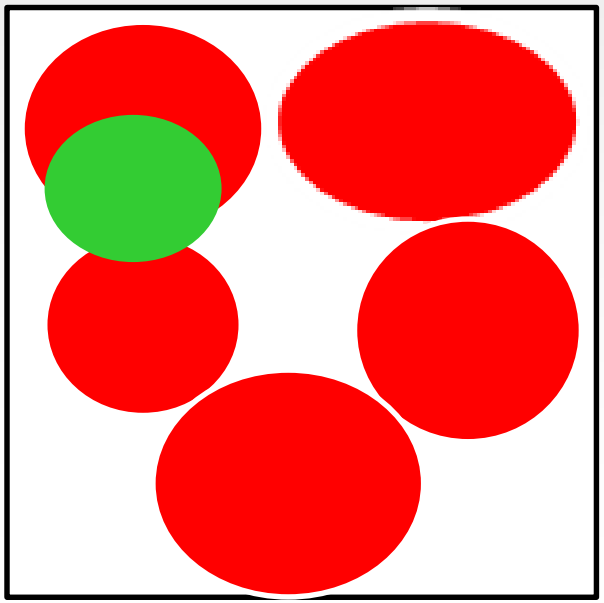
Childhood



Adolescence



Adulthood

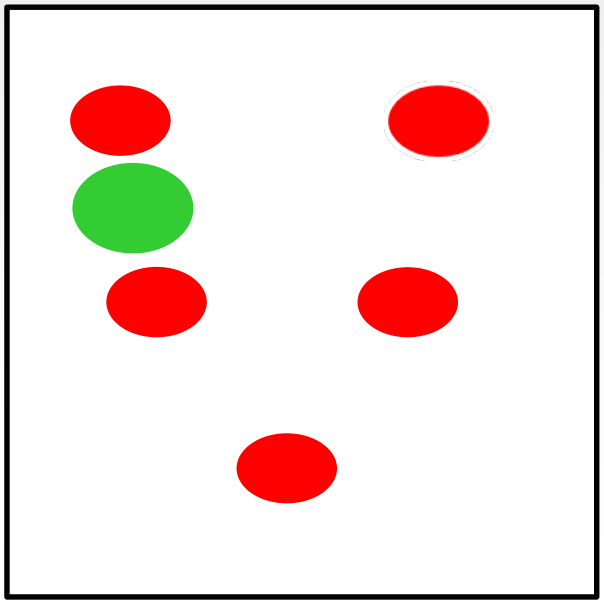


How do SLM and SLM-r account for age effects?

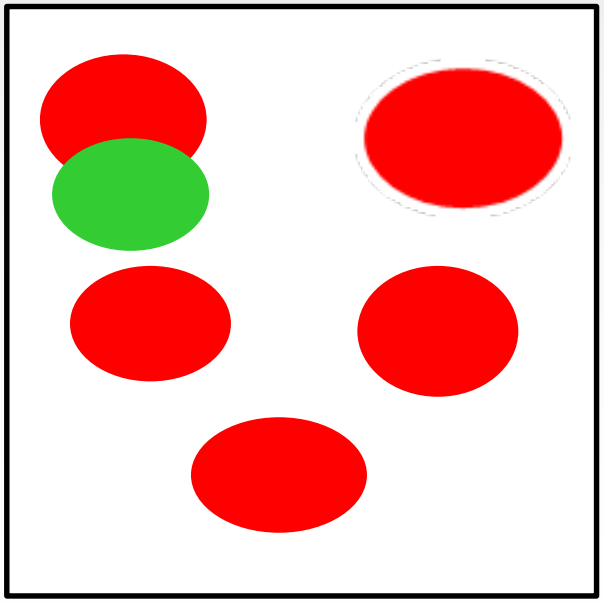
Evolution of phonetic categories over the life span accounts for age effects: Formation of categories for L1 sounds is likely to be blocked by equivalence classification in older learners

New category formation <----------> equivalence classification

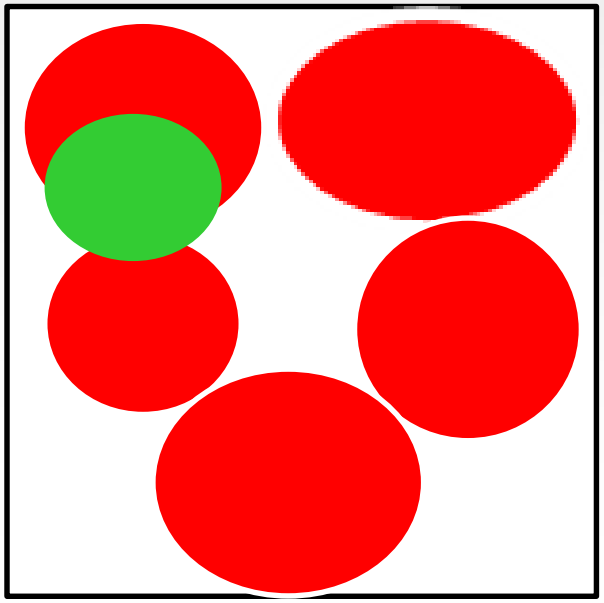
Childhood



Adolescence



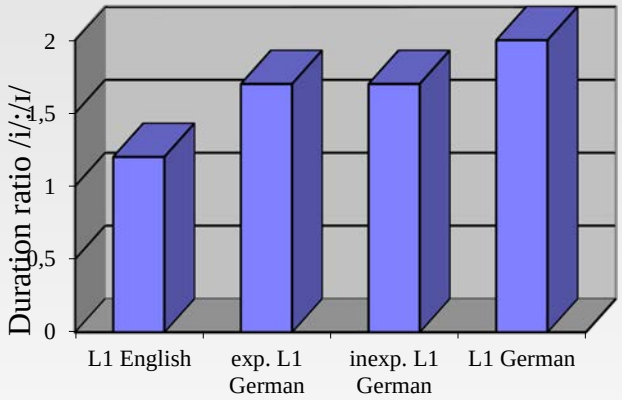
Adulthood

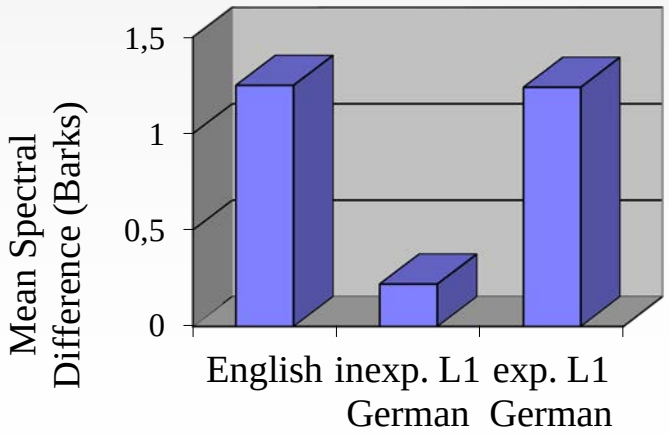


How do SLM and SLM-r account for age effects?

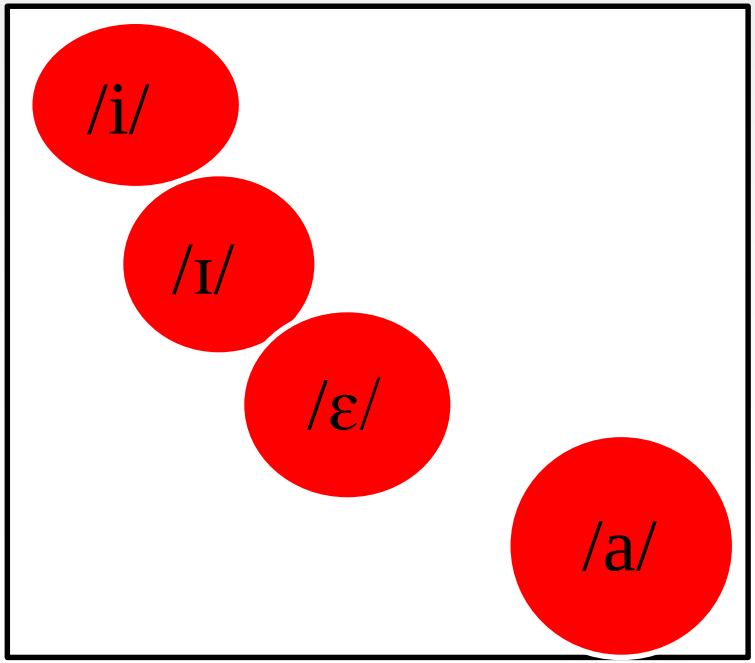
Example (Bohn Flege 1992):

L1 German speakers do not produce English /i - ɪ/correctly, but are (fairly) successful at English /æ/





German and English front vowels



How do SLM and SLM-r account for age effects?

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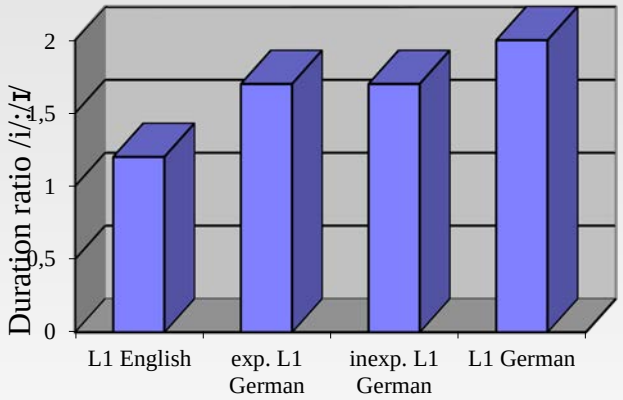

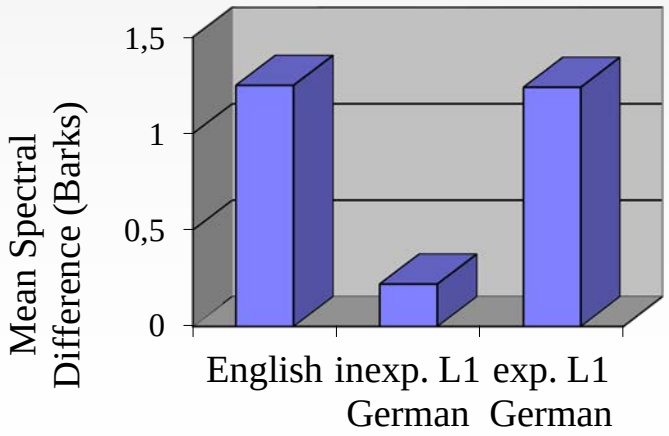

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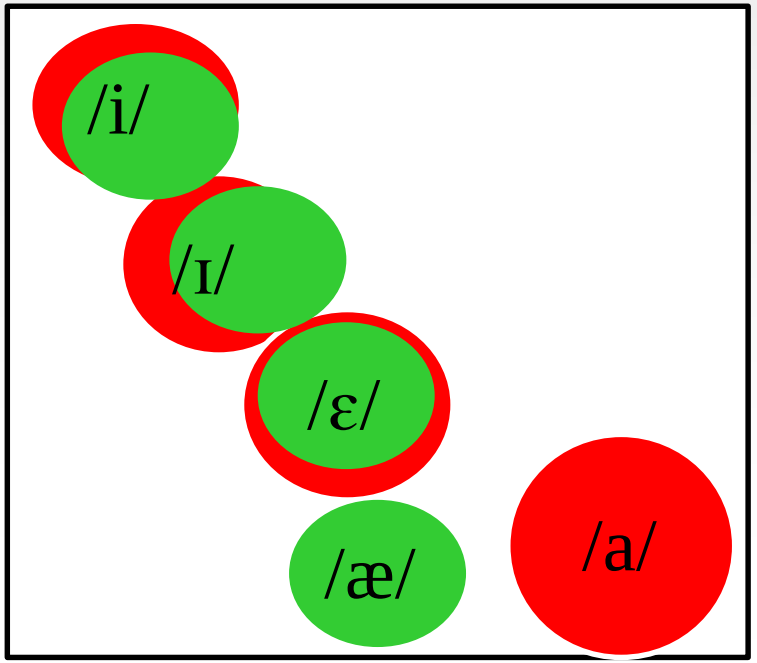


Core aspects of the revised Speech Learning Model (SLM-r)

Structure of talk:

- What is the Speech Learning Model?
- Unchanged aspects of the SLM in the SLM-r
- **Clarifications of the SLM in the SLM-r**
- New aspects of the SLM-r
- Open questions

Clarifications of the SLM in the SLM-r

SLM-r focus on

- effects of learning age
- effects of L2 experience
- input differences: Monolinguals vs bilinguals
- input differences: Child vs adult learners

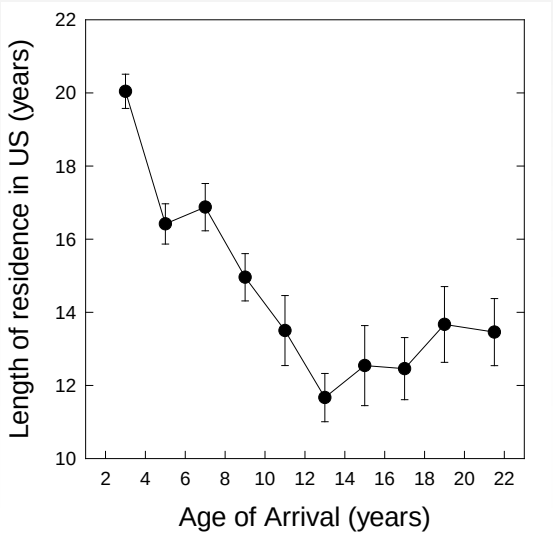
Clarifications of the SLM in the SLM-r

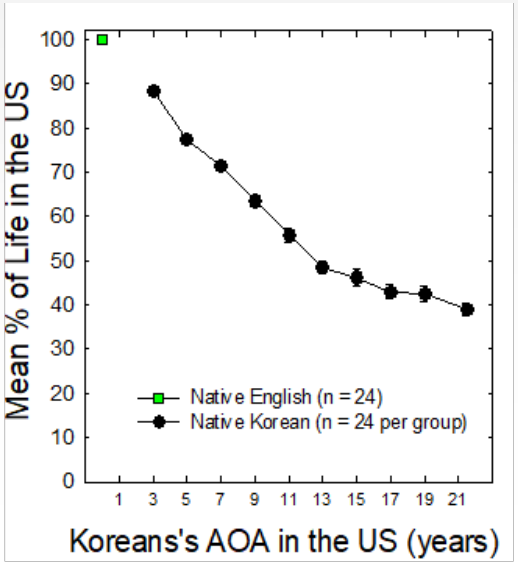
SLM-r focus on

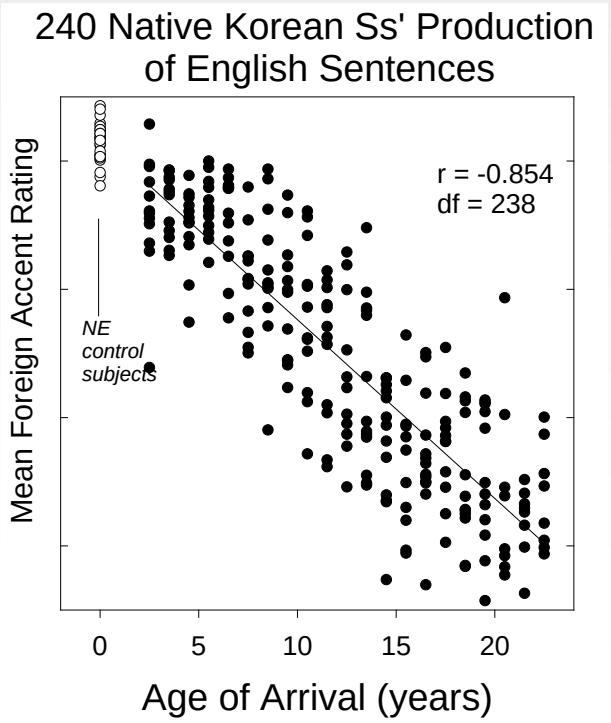
- effects of learning age
- effects of L2 experience

Note: Both SLM and SLM-r warn against age x experience confounds

Flege, Yeni-Komshian & Liu (1999)







Clarifications of the SLM in the SLM-r

Illustration of possible age x experience confound

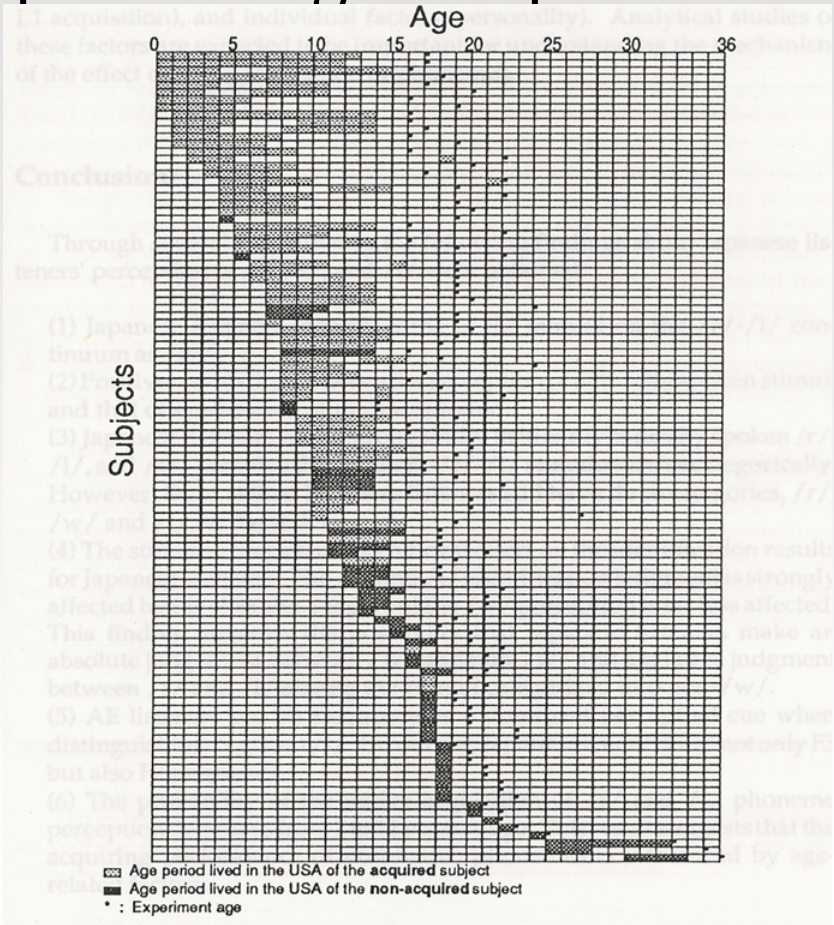


Figure 9. The relationship between the living period in the U.S. and the acquisition of /r/ and /l/ phonemes. Each row shows the experience of living in the U.S. for each subject who had once resided in the U.S. The living periods in the U.S. are represented with gray cells; the subjects whose living periods in the U.S. are represented with light gray showed native-like perception, and the subjects whose living periods in the U.S. are represented with dark gray showed results similar to the Japanese subjects who had no experience residing abroad. * mark represents the age at the time of the experiments.

Yamada & Tohkura (1991)

Clarifications of the SLM in the SLM-r

Two previous graphs:

Length of Residence (LOR) = L2 experience

Valid? Justified?

Flege, Bohn & Jang (1997):

2-way comparison:

L1 (Mandarin, Spanish, German, Korean) x

L2 experience (inexperienced vs. experienced)

TABLE I. Characteristics of the four relatively experienced and inexperienced groups of non-native speakers, each with five male and five female subjects. Standard deviations are in parentheses

Native language	L2 experience	Chron. age	Res. in US[a]	Arrival age[b]	Educ. in English[c]	% Use[d]
German	Experienced	33(6)	7.4(2.5)	25(5)	7(2)	87(15)
	Inexperienced	28(6)	0.6(0.4)	28(6)	8(2)	67(26)
Spanish	Experienced	28(6)	9.0(5.2)	20(5)	7(4)	75(11)
	Inexperienced	26(3)	0.4(0.1)	26(4)	6(3)	68(24)
Mandarin	Experienced	28(3)	5.4(2.4)	23(4)	6(2)	51(22)
	Inexperienced	28(3)	0.9(0.6)	27(3)	7(2)	32(15)
Korean	Experienced	31(7)	7.3(4.5)	24(5)	9(2)	59(9)
	Inexperienced	27(2)	0.8(0.3)	27(2)	10(3)	43(20)
	Mean (SD) Range	29(5) 20–45	4.0(4.3) 0.2–23	25(5) 14–38	8(3) 2–16	60(24) 20–100

[a] Res. in US; Length of residence in the US, in years.
[b] Arrival Age, Age of arrival in the US, in years.
[c] Educ. in English, Years of formal education in English prior to arrival in the US.
[d] % Use, Self-estimated percentage daily use of English.

Clarifications of the SLM in the SLM-r

Two previous graphs:

Length of Residence (LOR) = L2 experience

Valid? Justified?

NO!!

LOR is not a valid index of L2 experience

SLM-r:

Replace LOR with FTE (Full Time Equivalent) of L2 input

Clarifications of the SLM in the SLM-r

SLM-r:

~~Length of Residence~~

→ FTE (Full Time Equivalent) of L2 input

FTE: product of LOR x percentage L2 use

Example from Flege, Bohn & Jang (1997)

Experienced L1 German learners: LOR 7.4 years x 87% English use: **6.4 years of FTE**

Experienced L1 Korean learners: LOR 7.3 years x 59% English use: **4.3 years of FTE**

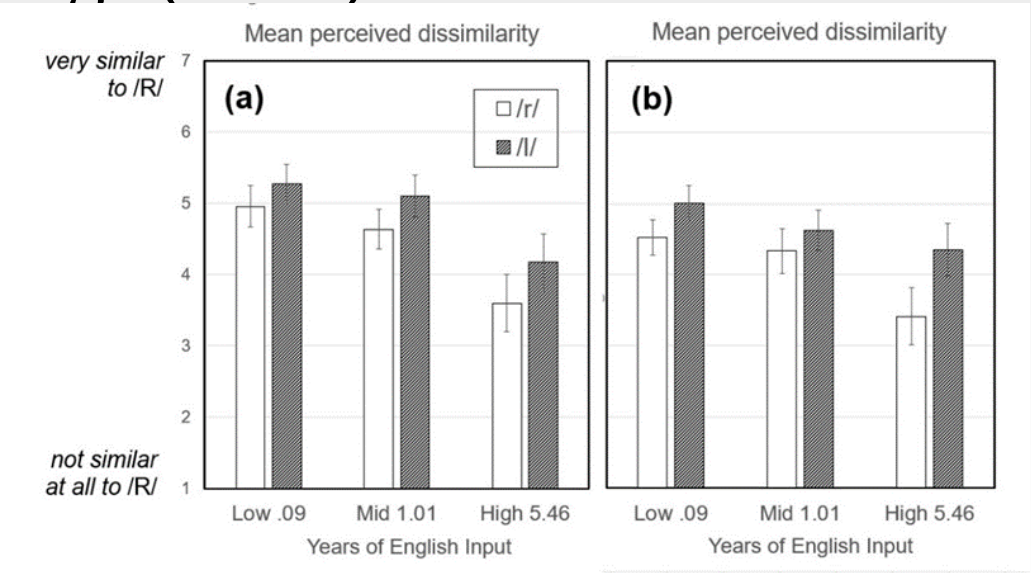
Clarifications of the SLM in the SLM-r

SLM-r:

FTE is a somewhat better estimate

of L2 input than LOR alone

Example: Aoyama & Flege (2011)



Mean perceived dissimilarity of English /r/ and /l/ in (a) single talker, (b) 5-talker condition as a function of FTE years of English input

Clarifications of the SLM in the SLM-r

SLM-r:

FTE is a somewhat better estimate

of L2 input than LOR alone

BUT: Problems remain

Self-reports (e.g., overall % L2 use) are estimates, not measurements

Important question: What kind of L2 input? (Quantity vs quality)

We can be certain:

Input which monolinguals receive ≠ input which bilinguals receive

Clarifications of the SLM in the SLM-r

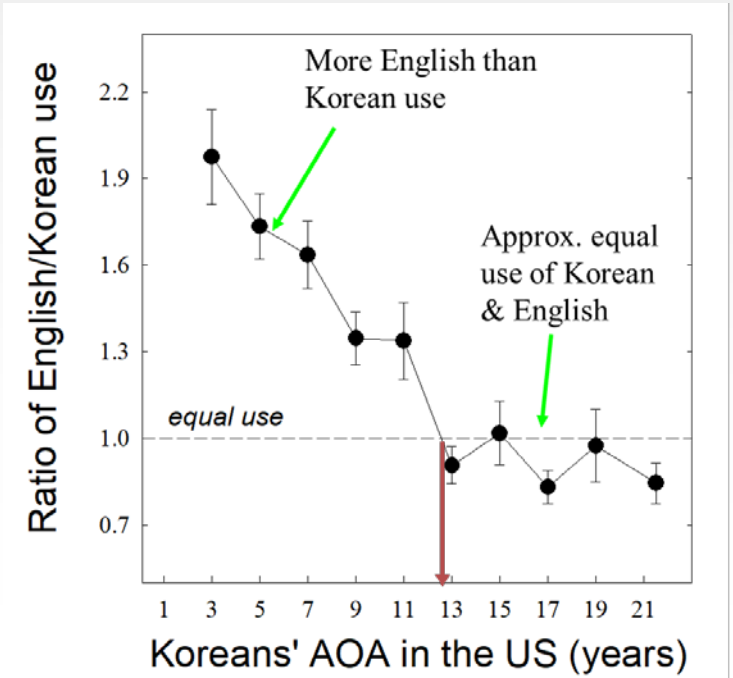
SLM-r:

Sharper focus on L2 input

Differences between the input received by monolinguals vs bilinguals

- Known that the later an L2 is learned, the less the L2 is used and the more the L1 continues to be used

Flege, Yeni-Komshian & Liu (1999)



BTW, note cross-over from primarily L2 (English) to L1 (Korean) use

Clarifications of the SLM in the SLM-r

SLM-r:

Sharper focus on L2 input

Differences between the input received by monolinguals vs bilinguals

- Known that the later an L2 is learned, the less the L2 is used and the more the L1 continues to be used

Differences between the input received by child vs adult learners

- Likely that late learners receive more foreign-accented L2 input than early learners (however, no hard evidence)

→ Early learners get more/”better” L2 input than late learners

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New aspects of the SLM-r

Here: Four important aspects, for equally important aspects see
Flege & Bohn (2021) and
Flege, Aoyama, & Bohn (2021)

- SLM focus on ultimate attainment/”end state”: Mistaken, unproductive
- Perception and production co-evolve
- Full access does away with feature hypothesis
- Individual differences, not group differences

New aspects of the SLM-r

SLM-r focus on L2 speech development, not just ultimate attainment/"end state"

SLM focus on highly experienced L2 learners assumed:

"At some point, L2 speech learning reaches an asymptote or 'ultimate' level of attainment."

Wide acceptance of "fossilization" notion in L2 research literature (e.g., Han & Odlin 2006), but no evidence for L2 speech learning.

Actually, fair amount of solid counterevidence:

NO end state in speech development (no matter whether L1 or L2)

New aspects of the SLM-r

NO end state in speech development (no matter whether L1 or L2)

Bloomfield (1933, 46): “The infant learns to speak like the people around him, but we must not picture this learning as coming to any particular end: There is no hour or day when we can say that a person has finished learning to speak, but, rather, to the end of his life, the speaker keeps on doing the very things which make up infantile language-learning. … Every speaker’s language … is a composite result of what he has heard other people say.”

Harrington, Palethorpe & Watson (2000):
Does the Queen speak the Queen’s English?

We conclude that the Queen no longer speaks the Queen’s English of the 1950s,

New aspects of the SLM-r

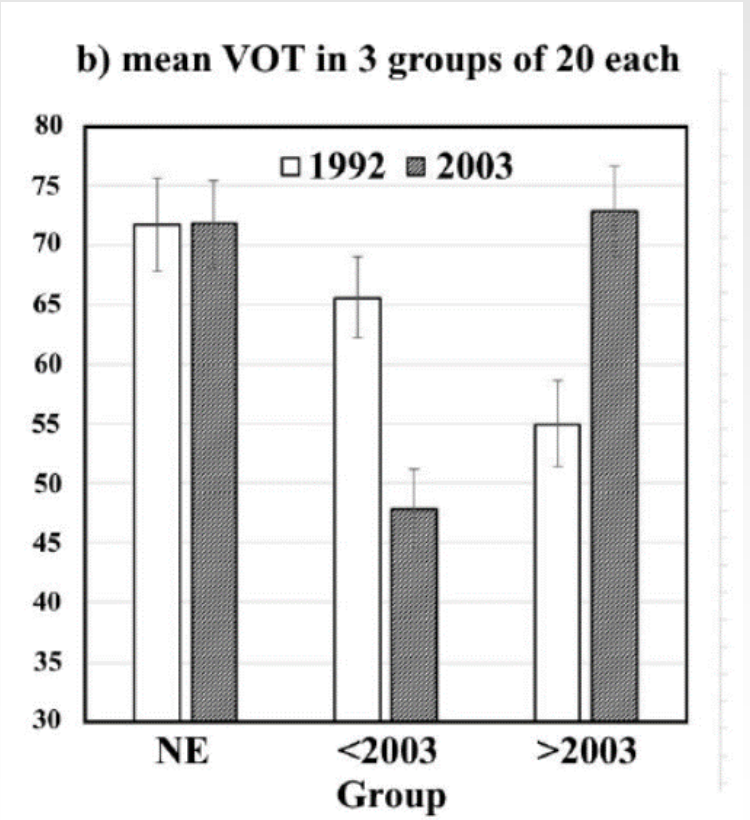
NO end state in speech development (no matter whether L1 or L2)

Flege, Munro, McKay (1995b):

Mean VOT (ms) in word-initial English /p t k/ in 1992 and in 2003,
Native English speakers (NE) and Native Italian speakers.

Native Italian speakers had spent **at least 15 years in Canada** in 1992 (15-44 years).

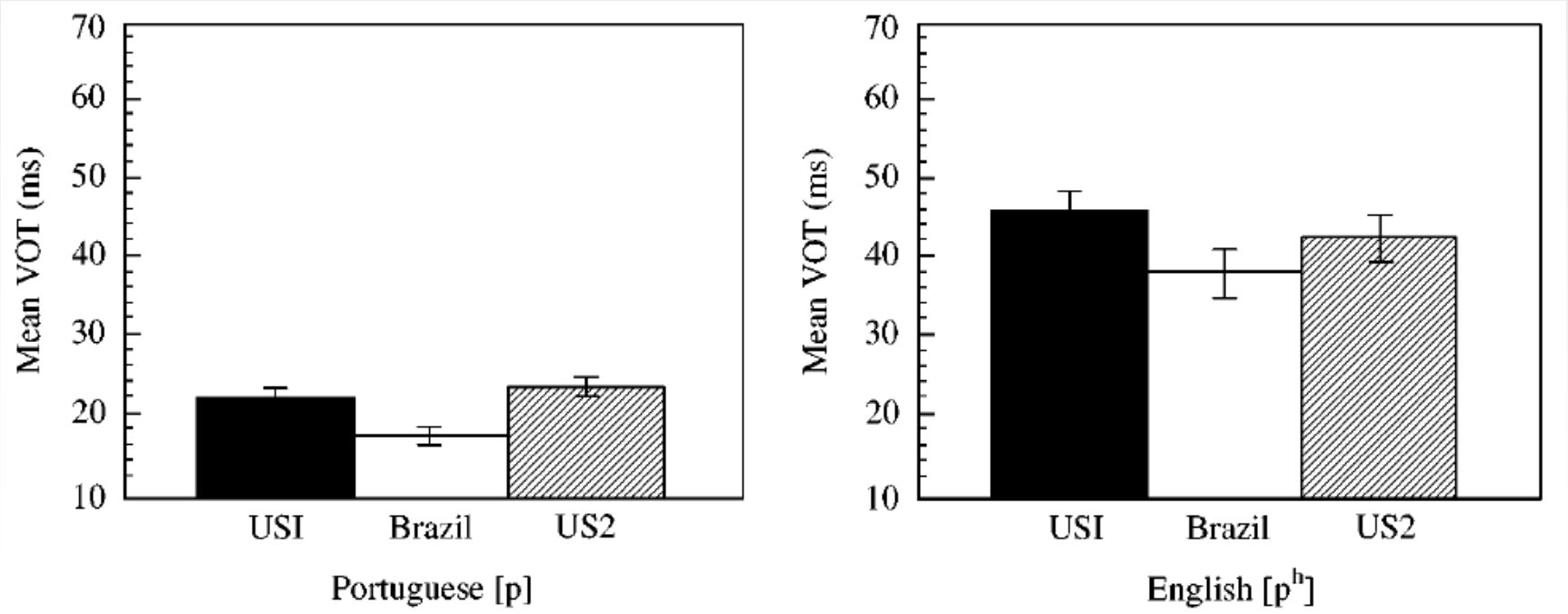
Native Italian speakers reported using English more (> 2003) or less (< 2003) in 2003 vs 1992.



New aspects of the SLM-r

NO end state in speech development
(no matter whether L1 or L2)

Sancier & Fowler (1997) VOT production changes in L1 and L2 **after two months**):



New aspects of the SLM-r

NO end state in speech development
(no matter whether L1 or L2)

Chang (2012): ”Rapid … effects of L2 learning in L1 speech production”

Naive, functionally monolingual L1 English learners of Korean, 6 week intensive Korean language course:

”Pervasive influence of L2 experience on L1 representations” for VOT, vowels.

New aspects of the SLM-r

NO end state in speech development (no matter whether L1 or L2)

All this (plus more evidence):

- The SLM-r no longer focuses on individuals who are highly experienced in the L2.

It is impossible for L2 learners to produce and perceive an L2 sound exactly like mature monolingual native speakers of the target L2.

- It is no longer of theoretical interest to determine if the L2 performance of a particular learner is or is not indistinguishable from that of L2 native speakers.

New aspects of the SLM-r

Perception and production co-evolve

SLM: Accuracy of L2 perception places an upper limit on L2 production accuracy.

Reasons:

- Perception precedes production in L1 development (Eilers & Oller 1976, Kuhl 2000).
- Nonnative speakers = native speakers in ability to scale degree of foreign accent (Flege 1988, Højen 2002)
- Perceptual training -> improved production (without training production, Bradlow et al. 1999, Sereno & Wang 2007)
- Positive correlations between production and perception accuracy (Flege 1999, Baker & Trofimovich 2006)

New aspects of the SLM-r

Perception and production co-evolve

SLM: Accuracy of L2 perception places an upper limit on L2 production accuracy.

What's wrong with the "upper limit" hypothesis?

- Near-mergers in L1: Speakers produce differences that they cannot (readily) perceive (e.g., Labov 1994)
- L2 speech: Studies which reported no positive or even inverse correlations (Sheldon & Strange 1982, Darcy & Krüger 2012, Bohn & Flege 1997)
- Correlations – if found - do not demonstrate causality

New aspects of the SLM-r

Perception and production co-evolve

SLM: Accuracy of L2 perception places an upper limit on L2 production accuracy.

SLM-r: L2 perception and production co-evolve without precedence.

"Co-evolution" hypothesis due to

- inconsistencies in L2 research and
- evidence that a strong bidirectional connection exists between production and perception.

New aspects of the SLM-r

No feature hypothesis: Full access

SLM: L2 learners cannot access features (or perceptual cues) which define L2 categories but are not exploited in the L1

SLM: L2 learners continue to weight features (or perceptual cues) in L1-like fashion, even if weighted differently in L2.

This feature hypothesis:
Incongruent with basic SLM (and SLM-r) assumption:

“Mechanisms and processes used in learning the L1 sound system … remain intact over the life-span and can be applied to L2 learning” (Flege 1995, 239).

New aspects of the SLM-r

SLM-r: Full access

Evidence for full access from L2 **vowel** studies:

- Iverson & Evans (2007): Nonnatives with L1s which make no/little use of duration and formant movement use these dimensions when selecting best exemplars of English vowels.

- Flege, Bohn, Jang (1997)

TABLE IV. The mean temporal and spectral effect scores obtained for the nine groups

		beat vs. bit		*bet vs. bat*	
Native language	L2 experience	Temporal effect	Spectral effect	Temporal effect	Spectral effect
English	—	**11/9**	**88/88**	**15/15**	**98/98**
German	Experienced	30/32	64/64	45/45	70/70
	Inexperienced	36/35	63/63	59/59	43/38
Spanish	Experienced	46/16	50/-6	19/19	88/88
	Inexperienced	50/46	44/13	12/12	94/94
Mandarin	Experienced	29/29	60/59	35/22	42/40
	Inexperienced	85/85	11/0	72/54	17/11
Korean	Experienced	66/66	29/-24	54/4	31/16
	Inexperienced	81/81	15/-4	66/-49	24/9

(similarly: Kim, Clayards, Goad 2018)

New aspects of the SLM-r

SLM-r: Full access

Evidence for full access from L2 **consonant** studies:

- Voicing in intial stop consonants:

English cues: VOT always primary, F0 secondary

Korean cues: F0 often primary, VOT often secondary

Kong & Yoon (2013): Sensitivity to F0 in L1 Korean L2 English in stop perception: Reduced in high English-proficiency L1 Koreans

- Voicing in final stop consonants:

English primary cue: Preceding vowel duration

Russian primary cue: Glottal pulsing during closure

Dmitrieva (2019): L1 Russian L2 English use preceding vowel duration as primary cue

New aspects of the SLM-r

Not group but individual differences

SLM: Focus on between-**group** differences (child vs adult learners, experienced vs inexperienced L2 learners)

SLM-r: Focus on how **individuals** learn L2 sounds:

Individual differences model

Attempt to account for intersubject differences in L2 production and perception

New aspects of the SLM-r

SLM-r is an individual differences model

How to account for intersubject differences
in L2 production and perception:

Individuals differ in

- How they specify L1 phonetic categories (in terms of cue weighting and degree of category precision) when they begin learning an L2;
- How they map L2 sounds onto L1 categories;
- How dissimilar they perceive L2 sounds to be from the closest L1 sound in their individual phonetic inventory
- How much and what kind of L2 input they receive.

Additionally, individuals differ in endogenous factors:

- Auditory acuity, working auditory memory

New aspects of the SLM-r

SLM-r is an individual differences model

L2 speech learning is affected by

- How L2 learners specify L1 phonetic categories (in terms of cue weighting and degree of category precision) when they begin learning an L2;

e.g., Clayards (2018): Differences in cue weights in native perception of:

Table 1. Minimal pairs and the primary (cue A) and secondary (cue B) cues manipulated in the study.

Minimal Pair	Cue A	Cue B
bet-bat	Formant frequency	Vowel duration
bog-dog	Vowel transition	Release burst
dear-tear	VOT	Onset f0
Luce-lose	Duration ratio	Vowel transition
sock-shock	Frication noise	Vowel transition

New aspects of the SLM-r

SLM-r is an individual differences model

L2 speech learning is affected by

- How L2 learners map L2 sounds onto L1 categories and how dissimilar they perceive L2 sounds to be from the closest L1 sound in their individual phonetic inventory

e.g., Mayr, R., & Escudero, P. (2010). Explaining individual variation in L2 perception: Rounded vowels in English learners of German.

Table 4. *Results per learner and vowel in the perceptual assimilation task (Experiment 1).*

Input→ Listener↓	uː	yː	øː	œ	ʊ	ʏ
NE1_1	[uː]-5, [ɔʊ]-3	[uː]-8	[ɔʊ]-6, [uː]-2	[ʊ]-3, [ʌ]-3	[ʊ]-6, [ʌ]-2	[ʌ]-4, [ʊ]-3
NE1_2	[uː]-4, [ɔʊ]-3	[uː]-8	[ɔʊ]-5, [ɔː]-2	[ʊ]-2, [ʌ]-2, [ɒ]-3	[ʊ]-5, [ʌ]-2	[ʊ]-8
NE1_3	[uː]-8	[uː]-8	[ɜː]-7	[ɜː]-8	[ʊ]-6, [uː]-[ʌ]-1	[ʊ]-5, [uː]-2, [ʌ]-1
NE1_4	[uː]-8	[uː]-7	[ɜː]-6	[ʌ]-5, [ʊ]-2	[ʊ]-8	[ʊ]-7
NE1_5	[uː]-7	[uː]-8	[ɜː]-8	[ɜː]-8	[ʊ]-6, [ʌ]-2	[ʊ]-4, [ʌ]-2, [uː]-2
NE1_6	[uː]-8	[uː]-8	[ɜː]-8	[ɜː]-5, [ʌ]-3	[ʊ]-6	[ʊ]-8
NE1_7	[uː]-5	[uː]-8	[ɜː]-7	[ɜː]-4, [ʊ]-2	[ʊ]-5	[uː]-4, [ʊ]-2, [ɜː]-2
NE2_8	[uː]-8	[uː]-8	[ɜː]-4, [uː]-3	[ɜː]-6, [ʊ]-2	[ʊ]-8	[ʊ]-8
NE2_9	[uː]-8	[uː]-8	[ɜː]-8	[ɜː]-7	[ʌ]-5, [ʊ]-3	[uː]-3, [ʌ]-3, [ʊ]-2
NE2_10	[uː]-6, [ɔʊ]-2	[uː]-8	[ɜː]-8	[ɪ]-5, [ɜː]-2	[ʌ]-7	[ɪ]-4, [uː]-3
NE2_11	[ɔː]-7	[uː]-8	[ɜː]-5, [uː]-3	[ɜː]-6	[ɔː]-3, [ʊ]-2	[ʊ]-4, [uː]-3
NE2_12	[uː]-7	[uː]-8	[ɜː]-8	[ɜː]-5, [ʊ]-3	[ʊ]-8	[ʊ]-8
NE2_13	[uː]-5, [ɔː]-2	[uː]-7	[ɜː]-8	[ɜː]-4, [ʌ]-4	[ʌ]-8	[uː]-2, [ʌ]-2, [ʊ]-2, [ɜː]-2
NE2_14	[uː]-8	[uː]-8	[ɜː]-4, [uː]-4	[ʌ]-6	[ʌ]-6	[ʊ]-4, [ʌ]-4
NE2_15	[uː]-8	[uː]-8	[ɔʊ]-8	[ʌ]-4, [ʊ]-3	[uː]-3, [ʊ]-2, [ɔʊ]-2	[uː]-4, [ɔʊ]-3

New aspects of the SLM-r

SLM-r is an individual differences model

L2 speech learning is affected by

- How much and what kind of L2 input learners receive

Flege, Bohn & Jang (1997):

Consider large SD for % self-estimated daily use of English

and range: 20-100 % self-estimated daily use of English

TABLE I. Characteristics of the four relatively experienced and inexperienced groups of non-native speakers, each with five male and five female subjects. Standard deviations are in parentheses

Native language	L2 experience	Chron. age	Res. in US[a]	Arrival age[b]	Educ. in English[c]	% Use[d]
German	Experienced	33(6)	7.4(2.5)	25(5)	7(2)	87(15)
	Inexperienced	28(6)	0.6(0.4)	28(6)	8(2)	67(26)
Spanish	Experienced	28(6)	9.0(5.2)	20(5)	7(4)	75(11)
	Inexperienced	26(3)	0.4(0.1)	26(4)	6(3)	68(24)
Mandarin	Experienced	28(3)	5.4(2.4)	23(4)	6(2)	51(22)
	Inexperienced	28(3)	0.9(0.6)	27(3)	7(2)	32(15)
Korean	Experienced	31(7)	7.3(4.5)	24(5)	9(2)	59(9)
	Inexperienced	27(2)	0.8(0.3)	27(2)	10(3)	43(20)
	Mean (SD) Range	29(5)	4.0(4.3)	25(5)	8(3)	60(24)
		20–45	0.2–23	14–38	2–16	20–100

[a] Res. in US; Length of residence in the US, in years.
[b] Arrival Age, Age of arrival in the US, in years.
[c] Educ. in English, Years of formal education in English prior to arrival in the US.
[d] % Use, Self-estimated percentage daily use of English.

New aspects of the SLM-r

SLM-r is an individual differences model

L2 speech learning is affected by

- Endogenous factors such as auditory acuity and working auditory memory

  Kempe et al. (2012). Individual differences in the discrimination of novel speech sounds: Effects of sex, temporal processing, musical and cognitive abilities. *PloS one*, *7*(11), e48623.

Kidd, G. R., Watson, C. S., & Gygi, B. (2007). Individual differences in auditory abilities. Journal of the Acoustical Society of America, 122(1), 418-435.

TABLE I. A summary of the 19 subtests of the extended version of the Test of Basic Auditory Capabilities (TBAC-E).

Subtest	Stimulus	Detect/identify	Manipulation
(1) Pitch discrimination	250-ms 75 dB SPL 1000 -Hz tone	ΔF	Frequency
(2) Single-tone intensity discrimination	250-ms 75 dB SPL 1000 -Hz tone	ΔI	Intensity
(3) Single-tone duration discrimination	100-ms 75 dB SPL 1000 -Hz tone	ΔT	Duration
(4) Pulse-train discrimination	Rhythmic sequence of six 20-ms 1000-Hz tones	ΔT	Relative duration of pauses between tones
(5) Embedded test-tone loudness	Sequence of nine (or eight) contiguous 40-ms tones (300–3000 Hz)	Presence/absence of middle tone	Duration of middle tone
(6) Temporal order for tones	Sequence of four contiguous tones (550–710 Hz)	Change in temporal order of middle two tones	Duration of middle two tones
(7) Temporal order for syllables	Sequence of four contiguous CV syllables	Change in temporal order of middle two syllables	Syllables duration
(8) Syllable identification	VC syllables in cafeteria noise	Syllable (3AFC)	Natural variation in cafeteria noise
(9–12) Sinusoidal amplitude modulation detection	500-ms noise sample with sinusoidal amplitude modulation (8, 20, 60, and 200 Hz)	Presence of AM	Modulation depth
(13) Ripple noise discrimination	500-ms noise sample with spectral "ripple"	Presence of ripple	Ripple depth
(14) Gap detection	750-ms noise sample	Silent gap in temporal center	Gap duration
(15) Gap duration discrimination	750-ms noise sample	Change in gap duration	Gap duration
(16) Nonsense syllable identification	Nonsense CVC syllable in noise	Syllable (4AFC)	S/N
(17) Word identification	One, two, and three-syllable words, in noise	Word (4AFC)	S/N
(18) Sentence identification	Meaningful sentences (4 to 10 words) in noise	Sentence (free recall)	S/N
(19) Environmental sound recognition	Familiar environmental sounds in noise	Familiar sounds (3AFC)	S/N

Summary so far

SLM-r retains from SLM

Phonetic categories are shaped and formed by ambient language(s) regardless of age

Learnability is a function of cross-language similarity

SLM-r clarifies SLM

Length of Residence is insensitive to language use patters

Full Time Equivalent: LOR x proportion of L2 use

Sharper focus on L2 input (quantity and quality in relation to e.g., age of learning)

SLM-r differs from SLM

NO end state in speech development: L2 learners will not produce and perceive L2 sounds exactly like mature monolingual native speakers of the target L2

Perception and production co-evolve: No precedence of perception

Full access to cues and features not exploited by L1

Individual differences model: Focus on how **individuals** learn L2 sounds:

Individual differences in specification of L1 phonetic categories, mapping of L2 sounds onto L1 categories, perception of L1-L2 sound dissimilarity, quality and quantity of L2 input, endogenous factors (auditory acuity and working auditory memory)

Core aspects of the revised Speech Learning Model (SLM-r)

Structure of talk:

- What is the Speech Learning Model?
- Unchanged aspects of the SLM in the SLM-r
- Clarifications of the SLM in the SLM-r
- New aspects of the SLM-r
- **Open questions**

Open questions

Here: Just two

How should we assess cross-language similarity?

How do universal perceptual biases interact with L1-induced biases?

Open questions

How should we assess cross-language similarity?

SLM-r, like SLM, PAM, PAM-L2, etc. depend in valid measure of cross-language similarity.

Flege & Bohn (2021) note that its importance ”is widely accepted but a standard measurement procedure has not yet emerged (for discussions, see Bohn, 2002; Strange, 2007). Cross-language dissimilarity must be assessed perceptually rather than acoustically because acoustic measures sometimes diverge from what listeners perceive” (e.g., Strange, Bohn, Trent, & Nishi 2004, Levy & Strange, 2008).

For discussion and suggestions, see also my lecture

“Predicting difficulty in L2 speech learning”

Open questions

How do universal perceptual biases interact with L1-induced biases?

Assumption of SLM, SLM-r, PAM, PAM-L2: (Most) L2 speech phenomena can be accounted for by cross-language phonetic relationships

SLM-r acknowledges existence of universal perceptual biases which all boil down to “the phonetic landscape … is an uneven terrain” (Nam & Polka 2016)

Examples of universal biases:

Natural Referent Vowels (Polka & Bohn 2003, 2011)

Natural Referent Consonants (Bundgaard-Nielsen et al. 2015)

Natural Referent Tones (Wayland et al. 2020)

For discussion and suggestions, see also my lecture

“Cross-language phonetic relationships account for most, but not all L2 speech learning problems”

rɔxt ful ʈ̪ʰŋk

bɛsn daŋk

mɑŋə t ɦak

θæŋk juː

muʧaʰ grasias

eskeriak asko

obrigadu

mɛrsɛs

djɔx

ɕie ɕie

aɾigato

ʤɛŋkujɛ

kamsamnida